


# A prospective, randomized trial comparing thulium vapoenucleation with holmium laser enucleation of the prostate for the treatment of symptomatic benign prostatic obstruction: perioperative safety and efficacy

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## Abstract

**Introduction and objectives** To compare the perioperative outcomes of thulium vapoenucleation of the prostate (ThuVEP) with holmium laser enucleation of the prostate (HoLEP) for patients with symptomatic benign prostatic obstruction (BPO).

**Methods** Forty-eight and 46 patients were prospectively randomized to ThuVEP and HoLEP. All patients were assessed preoperatively and 4-week postoperatively. The complications were noted and classified according to the modified Clavien classification system. Patient data were expressed as median (interquartile range) or numbers (%).

**Results** Median age at surgery was 73 (67–76) years and median prostate volume was 80 (46.75–100) cc and not different between the groups ( $p = 0.207$ ). The median operative time was 60 (41–79) minutes without significant differences between both groups ( $p = 0.275$ ). There were no significant differences between the groups regarding catheterization time [2 (2–2) days,  $p = 0.966$ ] and postoperative stay [2 (2–3) days,  $p = 0.80$ ]. Clavien 1 (13.8%), Clavien 2 (3.2%), Clavien 3a (2.1%), and Clavien 3b (4.3%) complications occurred without significant differences between the groups. However, the occurrence of acute postoperative urinary retention was higher after HoLEP compared to ThuVEP (15.2 vs. 2.1%,  $p \leq 0.022$ ). At 1-month follow-up, peak urinary flow rates (10.7 vs. 22 ml/s), post-void residual volumes (100 vs. 20 ml), International Prostate

Symptom Score (20 vs. 10) and Quality of Life (4 vs. 3) had improved significantly ( $p \leq 0.005$ ) without significant differences between the groups.

**Conclusions** ThuVEP and HoLEP are safe and effective procedures for the treatment of symptomatic BPO. Both procedures give equivalent and satisfactory immediate mic-turition improvement with low perioperative morbidity.

**Keywords** Benign prostatic obstruction, BPO · Vapoenucleation · Tm:YAG · Ho:YAG · HoLEP · ThuVEP · Laser surgery · Prostate

## Introduction

Although associated with considerable perioperative morbidity, transurethral resection of the prostate (TURP) and open prostatectomy (OP) have been the standard treatment for lower urinary tract symptoms (LUTS) secondary to benign prostatic obstruction (BPO) over decades [1, 2]. Since the introduction of holmium laser enucleation of the prostate (HoLEP) into the armamentarium of BPO treatment [3], HoLEP has been proven in numerous randomized controlled trials (RCT) to be a minimally invasive, size-independent method with excellent long-term results [4, 5]. Based on the HoLEP technique, alternative techniques for transurethral endoscopic enucleation of the prostate (EEP) have been described using different energy sources [6]. One prominent representative is the Thulium:YAG laser for thulium vapoenucleation of the prostate (ThuVEP) [7]. Although ThuVEP has been shown to be a size-independent procedure for the surgical treatment of BPO with low perioperative morbidity and good long-term results [8–10], RCTs have not been performed so far. The aim of this RCT was to compare the perioperative efficacy and safety

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between ThuVEP and HoLEP in patients with LUTS secondary to BPO and enlarged prostates.

## Methods

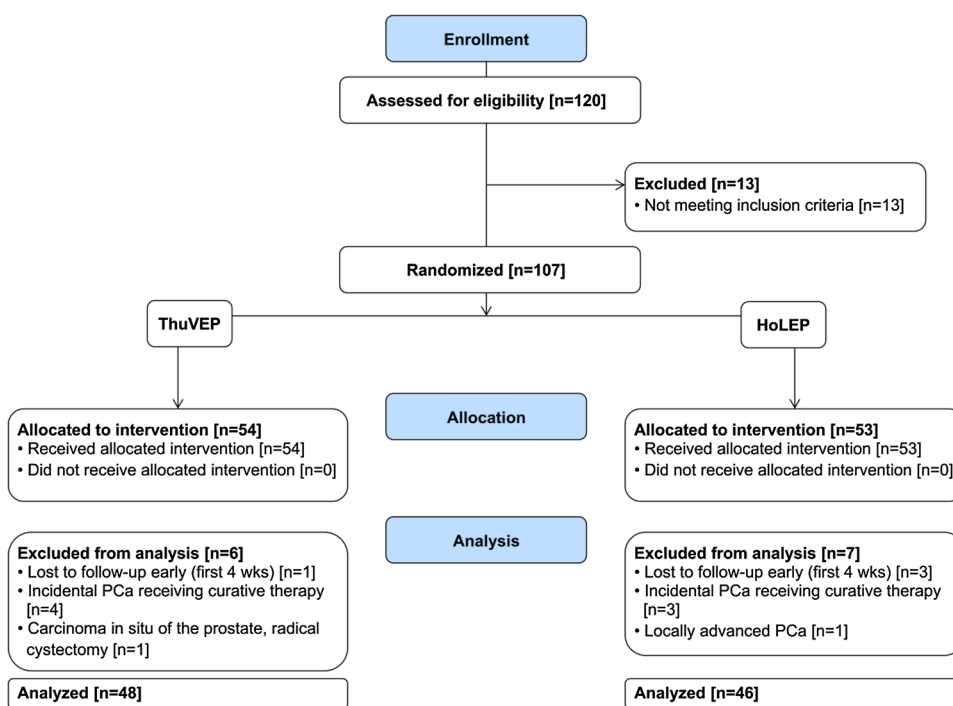
After institutional review board approval, an unicentric RCT was performed from January 2015 to February 2016 at the Asklepios Klinik Barmbek. This RCT was registered in the German Clinical Trials Register (DRKS-ID: DRKS00008206). Inclusion criteria were maximum urinary flow rate ( $Q_{\max}$ )  $\leq 15$  ml/s, International Prostate Symptom Score (IPSS)  $\geq 12$ , male patients  $\geq 18$  years, and/or failed medical therapy of BPO, recurrent urinary tract infections (UTI), and/or recurrent episodes of urinary retention. Exclusion criteria were previous urethral/prostatic surgery, known prostate cancer (PCa) or urethral strictures, and urodynamically diagnosed neurogenic bladder.

A total of 107 consecutive patients were randomly assigned in a 1:1 fashion using computer generated block randomization to HoLEP or ThuVEP (Fig. 1). Preoperative assessment included a physical examination with digital rectal examination, prostate volume by transrectal ultrasound, uroflowmetry, measurement of post-void residual urine (PVR), IPSS, quality of life (QoL), PSA assay, urine analysis, and urine culture.

All surgeries were performed by two surgeons (AJG, CN) who had performed more than 500 ThuVEP and 200 HoLEP procedures each. A 26F continuous-flow laser resectoscope in combination with a mechanical tissue

morcellator (Wolf Piranha<sup>®</sup>, Richard Wolf, Knittlingen, Germany) was used. ThuVEP was carried out using a 1940 nm continuous wave Tm: fiber laser (vela<sup>®</sup> XL, Boston Scientific, Ratingen, Germany) at 90 W, while HoLEP was performed using a 2080 nm pulsed Ho:YAG laser (Auriga<sup>®</sup> XL, Boston Scientific, Ratingen, Germany) at 39.6 W (2.2 Joule, 18 Hz). A 550- $\mu$ m bare-ended, re-usable laser fiber was used (LightTrail<sup>®</sup>, Boston Scientific, Ratingen, Germany). HoLEP and ThuVEP techniques have been previously reported in detail [7, 9, 11]. In brief, depending on the lobe configuration and the size of the prostate, a 2- or 3-lobe technique was performed in ThuVEP and in HoLEP. Briefly, the 2-lobe technique starts with a 5- or 7-o'clock incision with enucleation of one lateral lobe, followed by enucleation of the median and remaining lateral lobe as a single unit. The 3-lobe technique is used in large volume prostates with large median lobes. After 5- and 7-o'clock incisions down to the surgical capsule, the median lobe is enucleated in a retrograde manner. The lateral lobes are enucleated by dissecting the prostatic adenoma from the peripheral zone at the layer of the surgical capsule. ThuVEP and HoLEP were performed using the same 2- or 3-lobe techniques. At the end of surgery, a 22F three-way foley catheter was inserted for continuous bladder irrigation, which was finished the next morning according to standard department protocol. Routinely, the catheter was removed on the second postoperative day. All patients received a perioperative antibiotic regimen with a second generation cephalosporin routinely until removal of the catheter or antibiotics according to an antibiogram. Blood

**Fig. 1** The Consolidated Standards of Reporting Trials (CONSORT) E-flowchart shows the design of the study including randomisation and immediate treatment



loss was estimated by comparing the hemoglobin value before surgery with the corresponding value on the first postoperative day. Patients were discharged after removal of the catheter and after being able to void adequately.

All medical and surgical complications were noted and classified according to the modified Clavien classification system by four residents not involved in the surgeries (CM, AVB, CT, BB) [10, 12, 13]. All patients were reassessed one month after surgery by IPSS, QoL,  $Q_{\max}$ , and PVR.

The primary endpoints of the study were IPSS and  $Q_{\max}$  (ml/s). The secondary endpoints were operation/catheterization/hospitalization time, the complication rate (CR), QoL, and PVR assessments during follow-up. The sample size was calculated for the detection of statistically significant differences for the final analysis 2 years postoperatively. The follow-up is still ongoing and the estimated completion of 2-year follow-up data will be in 2018. With  $\alpha = 0.05$  (type I error, 0.025 adjusted for the 2 primary outcomes) and a power of 90% ( $\beta = 0.10$ ), a sample size of 32 patients per group was calculated. The calculation assumed that the relevant difference in IPSS was 3 (SD = 3) and in  $Q_{\max}$  it was 3 (SD = 6) ml/s. Since an overall yearly drop-out rate of about 15% was expected, 45 patients per group had to be recruited.

Using SPSS 22 (IBM Corp, Armonk, NY, USA), the two-tailed  $\chi^2$ -test or the Mann–Whitney  $U$  test were applied to determine the statistical significance of differences between various parametric and non-parametric parameters of the study groups. Improvement in the assessed parameters in each treatment arm was calculated using the paired  $t$  test. Patient data were expressed as median (interquartile range). A  $p$  value  $\leq 0.05$  was considered statistically significant.

## Results

Table 1 lists the baseline characteristics of the patients. There were no statistically significant differences in any baseline characteristics between the ThuVEP ( $n = 48$ ) and HoLEP ( $n = 46$ ) group. Fifty (53.2%) patients had a gland volume  $\geq 80$  ml, with 29 (30.9%) have glands  $\geq 100$  ml, respectively (Table 1).

Table 2 lists perioperative data. The operative time was 60 (41–79) minutes without differences between the groups, although enucleation time was significantly shorter for ThuVEP compared to HoLEP (27.3 vs. 40 min,  $p \leq 0.004$ ). There were no differences between the groups regarding catheterization time [2 (2–2) days] and postoperative stay [2 (2–3) days].

Tables 3 and 4 list detailed information on all complications and treatment modalities. Clavien 1 (13.8%), 2 (3.2%), 3a (2.1%), and 3b (4.3%) complications occurred

without differences between the groups. The most frequent complications were acute urinary retention (AUR) (8.5%), clot retention without surgical revision (4.3%), surgical revision due to bleeding (3.2%), and UTI (2.1%) (Table 4). The occurrence of postoperative AUR was significantly higher after HoLEP compared to ThuVEP (15.2 vs. 2.1%,  $p \leq 0.022$ ). The overall immediate CR was 23.4% (Table 3) and significantly higher after HoLEP compared to ThuVEP (12.5 vs. 33.3%,  $p \leq 0.015$ ).

At 4-week follow-up,  $Q_{\max}$ , PVR, and IPSS had improved significantly compared to baseline ( $p \leq 0.005$ ) without differences between the groups (Table 5), while QoL was significantly different between ThuVEP [2 (1–3)] and HoLEP [3 (2–5),  $p \leq 0.040$ ] (Table 5). One patient (2.1%) in the ThuVEP and 4 (8.7%) in the HoLEP group showed transient urge incontinence ( $p = 0.149$ ), while 9 (18.8%) in the ThuVEP group and 8 (17.4%) in the HoLEP group had transient stress incontinence after removal of the catheter ( $p = 0.491$ ). Stress incontinence recovered in all patients within one month. At 1-month follow-up, one patient in the ThuVEP group (2.1%) and one (2.1%) patient in the HoLEP group had urge incontinence.

## Discussion

The key results of our PRT were that ThuVEP and HoLEP are both safe and effective procedures in patients with LUTS secondary to BPO and enlarged prostates. Both procedures give equivalent and satisfactory immediate micriturition improvement with low perioperative morbidity at short-term follow-up.

The major benefit of transurethral EEP is combining the advantages of OP (complete dissection of the prostate adenoma from the prostatic pseudocapsule) with those of the transurethral approach (direct sealing of bleeding vessels). HoLEP was the most outstanding EEP procedure for the surgical treatment of BPO during the past two decades [4, 5]. HoLEP or EEP has been recommended by the current guidelines of the European Association of Urology in men with substantially enlarged prostates ( $>80$  ml) as first-line therapy [14]. However, only few PRT for EEP other than HoLEP [4, 5] and bipolar enucleation of the prostate (BipoleP) [15–22] are available: GreenLight laser enucleation of the prostate (GreenLEP) [23], thulium laser enucleation of the prostate (ThuLEP) [24, 25], eraser laser enucleation of the prostate (ELEP) [26], and diode laser enucleation of the prostate (DiLEP) [22, 27]. One prominent EEP technique is the ThuVEP procedure utilizing the Tm:YAG laser [6–10], but PRT for ThuVEP have not been published yet. We report the first results of a PRT comparing ThuVEP with HoLEP.

**Table 1** Baseline characteristics

	ThuVEP ( <i>n</i> = 48)	HoLEP ( <i>n</i> = 46)	Overall ( <i>n</i> = 94)	<i>p</i> value
Age (years)	74 (68–76.75)	71.5 (67–75)	73 (67–76)	0.207
No. of pts. ≥80 years (%)	7 (14.6)	4 (8.7)	11 (11.7)	0.313
ASA score	2 (2–2)	2 (2–3)	2 (2–3)	0.155
BMI (kg/m <sup>2</sup> )	26.84 (24.76–28.33)	27.72 (25.72–29.67)	27.12 (25.01–29.05)	0.160
Duration of LUTS (years)	4.5 (3–8)	4 (3–5)	4 (3.7–7.75)	0.175
No. alpha-blocker therapy (%)	41 (85.4)	42 (91.3)	83 (88.3)	0.313
No. 5- $\alpha$ -reductase inhibitor therapy (%)	12 (25)	14 (30.4)	26 (27.7)	0.407
No. 5- $\alpha$ -reductase inhibitor therapy and alpha-blocker therapy (%)	12 (25)	13 (28.3)	25 (26.6)	0.463
No. anticholinergic medications (%)	2 (4.2)	0 (0)	2 (2.1)	0.141
No. history of urinary retention (%)	26 (54.2)	20 (43.5)	46 (48.9)	0.264
No. preoperative urinary retention (%)	24 (50)	19 (41.3)	43 (45.7)	0.327
Median episodes of urinary retention ( <i>n</i> )	1 (1–2)	1 (1–2)	1 (1–2)	0.430
PSA (ng/ml)	4.14 (1.98–6.28)	4.14 (2.18–8.37)	4.14 (2.13–6.98)	0.698
Prostate volume (ml)	82.5 (47.75–100)	77.5 (45.75–110.25)	80 (46.75–100)	0.826
IPSS	20 (16–25)	22 (15–26)	20 (16–25)	0.809
QoL	4 (4–5)	4 (4–5)	4 (4–5)	0.889
<i>Q</i> <sub>max</sub> (ml/s)				
Preop	9.6 (6.2–12.4)	12.1 (7.2–15)	10.7 (6.43–14.85)	0.181
At discharge	16 (11.7–19.4)	13 (8.4–18)	16 (10.6–19)	0.162
<i>p</i> value (preop vs. discharge)	≤0.005	≤0.007	<0.001	
PVR (ml)				
Preop <sup>a</sup>	100 (26.75–237.5)	105 (48.25–200)	100 (38–200)	0.962
At discharge	38.5 (0–90)	20 (0–80)	30 (0–82.5)	0.674
<i>p</i> value (preop vs. discharge)	<0.001	<0.001	<0.001	
No. PVR ≥100 ml ( <i>n</i> )				
Preop	32 (66.7)	25 (54.3)	57 (60.6)	0.206
At discharge	6 (12.5)	9 (19.6)	15 (15.9)	0.297
IIEF-EF score	16.5 (6.75–25.25)	20 (9–27.25)	17 (9–26.75)	0.642
No. of associated conditions				
Arterial hypertension (%)	26 (54.2)	33 (71.7)	59 (62.8)	0.079
Hyperlipidaemia (%)	6 (12.5)	6 (13)	12 (12.8)	0.498
Diabetes mellitus (%)	3 (6.3)	5 (10.9)	8 (8.5)	0.341
Coronary heart disease (%)	5 (10.4)	9 (19.6)	14 (14.9)	0.199
Congestive heart failure (%)	1 (2.1)	1 (2.2)	2 (2.1)	0.499
Cardiomyopathy (%)	3 (6.3)	4 (8.7)	7 (7.4)	0.443
Coronary stent (%)	2 (4.2)	2 (4.3)	4 (4.3)	0.499
Drug eluting stent (%)	1 (2.1)	0 (0)	1 (1.1)	0.281
Atrial fibrillation (%)	0 (0)	1 (2.2)	1 (1.1)	0.267
Peripheral artery occlusive disease (%)	2 (4.2)	0 (0)	2 (2.1)	0.156
Chronic renal failure (%)	1 (2.1)	0 (0)	1 (1.1)	0.218
Status post myocardial infarction (%)	2 (4.2)	1 (2.2)	3 (3.2)	0.418
Status post stroke (%)	1 (2.1)	0 (0)	1 (1.1)	0.281
Inguinal hernia (%)	3 (6.3)	7 (15.2)	10 (10.6)	0.153
Bladder diverticulum (%)	0 (0)	1 (2.2)	1 (1.1)	0.267
Bladder stones <sup>b</sup> (%)	1 (2.1)	1 (2.2)	2 (2.1)	0.499
Dilation upper tract (%)	1 (2.1)	1 (2.2)	2 (2.1)	0.499
Recurrent UTI (%)	0 (0)	1 (2.2)	1 (1.1)	0.267
Treated UTI prior to surgery (%)	2 (4.2)	5 (10.9)	7 (7.4)	0.201
Surgery under ongoing anticoagulant therapy (%)	9 (18.8)	9 (19.6)	18 (19.1)	0.497

**Table 1** (continued)

	ThuVEP ( <i>n</i> = 48)	HoLEP ( <i>n</i> = 46)	Overall ( <i>n</i> = 94)	<i>p</i> value
Aspirin	8 (16.7)	6 (13.1)	14 (14.9)	0.433
Phenprocoumon <sup>c</sup>	1 (2.1)	0 (0)	1 (1.1)	0.282
Apixaban	0 (0)	1 (2.2)	1 (1.1)	0.267
Dabigatran	0 (0)	2 (4.3)	2 (2.1)	0.499
Anticoagulants temporarily stopped (%)	5 (10.4)	4 (8.7)	9 (9.6)	0.476
Aspirin	2 (4.2)	4 (8.7)	6 (6.4)	0.361
Phenprocoumon	2 (4.2)	0 (0)	2 (2.1)	0.141
Rivaroxaban	1 (2.1)	0 (0)	1 (1.1)	0.267

Data as *n* (%) or median (interquartile range)

*ThuVEP* thulium laser enucleation of the prostate, *HoLEP* holmium laser enucleation of the prostate, *LUTS* lower urinary tract symptoms, *PSA* prostate-specific antigen, *IPSS* International Prostate Symptom Score, *QoL* quality of life, *Q<sub>max</sub>* maximum urinary flow rate, *PVR* post-voiding residual urine, *ASA* American Society of Anaesthesiologists, *IIEF-EF* Erectile Function domain of the International Index of Erectile Function

<sup>a</sup> Except those in urinary retention

<sup>b</sup> Treated with Holmium laser endoscopic lithotripsy prior to the ThuVEP procedure

<sup>c</sup> Subtherapeutic dosage

**Table 2** Perioperative data

	ThuVEP ( <i>n</i> = 48)	HoLEP ( <i>n</i> = 46)	Overall ( <i>n</i> = 94)	<i>p</i> value
Operation time <sup>e</sup> (min)	50 (37.75–71.75)	65 (44–81)	60 (41–79)	0.275
Enucleation time <sup>f</sup> (min)	27.03 (21.53–37.65)	40 (29.75–50.09)	34.09 (25–45.03)	≤0.004
Morcellation time (min)	13 (9–20)	13.21 (9–20.5)	13.11 (9–19.75)	0.934
Morcellation efficiency <sup>a</sup> (g/min)	3.3 (2.5–6.10)	4.03 (2.98–5.03))	3.87 (2.7–5.33)	0.797
Enucleation efficiency <sup>b</sup> (g/min)	1.87 (1.18–2.59)	1.19 (0.85–1.86)	1.41 (0.99–2.13)	≤0.005
Operation efficiency <sup>c</sup> (g/min)	0.94 (0.69–1.21)	0.87 (0.59–1.14)	0.9 (0.65–1.18)	0.152
Resected weight (g)	58 (32.75–86.5)	48 (25–80)	53 (32–80)	0.421
Percentage resected tissue <sup>d</sup> (%)	64.67 (52.61–81.24)	71.11 (55.56–84.31)	68.97 (53.33–82.03)	0.550
Haemoglobin decrease (g/dl)	1.6 (1.1–2.35)	1.7 (0.7–2.6)	1.6 (1–2.5)+	0.970
Catheter time (days)	2 (2–2)	2 (2–2)	2 (2–2)	0.966
Postoperative stay (days)	2 (2–3)	2 (2–3)	2 (2–3)	0.809

Data indicated as median (interquartile range)

*ThuVEP* thulium laser enucleation of the prostate, *HoLEP* holmium laser enucleation of the prostate

<sup>a</sup> Resected weight/morcellation time

<sup>b</sup> Resected weight/enucleation time

<sup>c</sup> Resected weight/operation time

<sup>d</sup> Resected weight/preoperative prostate volume

<sup>e</sup> Measured from insertion until removal of the resectoscope

<sup>f</sup> Measured from insertion of the laser fiber until removal

**Table 3** Clavien grade 1 to 3b complications

Complication	ThuVEP ( <i>n</i> = 48)	HoLEP ( <i>n</i> = 46)	Overall ( <i>n</i> = 94)	<i>p</i> value
Clavien grade 1	4 (8.3)	9 (19.5)	13 (13.8)	0.144
Clavien grade 2	1 (2.1)	2 (4.3)	3 (3.1)	0.396
Clavien grade 3a	0 (0)	2 (4.3)	2 (2.1)	0.141
Clavien grade 3b	1 (2.1)	3 (6.5)	4 (4.3)	0.254
Total	6 (12.5)	16 (33.3)	22 (23.4)	≤0.015

*ThuVEP* thulium laser enucleation of the prostate, *HoLEP* holmium laser enucleation of the prostate

**Table 4** Detailed analysis of Clavien grade 1 to 3b complications within 30-day perioperative period

Complication	Treatment	ThuVEP ( <i>n</i> = 48)	HoLEP ( <i>n</i> = 46)	Overall ( <i>n</i> = 94)	<i>p</i> value
Clavien grade 1 complications ( <i>n</i> = 13 of 94; 13.8%)					
Urinary retention after catheter removal	Bedside recatheterization	1 (2.1)	3 (6.5)	4 (4.3) <sup>a</sup>	0.254
		0 (0)	4 (8.7)	4 (4.3) <sup>b</sup>	0.037
Clot retention without surgical revision	Bladder irrigation (prolonged) and tamponade evacuation through catheter	2 (4.2)	2 (4.3)	4 (4.3)	0.499
Superficial bladder injury due to morcellation	No special therapy	1 (2.1)	0 (0)	1 (1.1)	0.281
Clavien grade 2 complications ( <i>n</i> = 3 of 94; 3.2%)					
Postoperative Hematuria	Transfusion	0 (0)	1 (2.2)	1 (1.1)	0.267
Urinary tract infections	Antibiotics	1 (2.1)	1 (2.1)	2 (2.1)	0.499
Clavien grade 3a complications ( <i>n</i> = 2 of 94; 2.1%)					
Incomplete morcellation	Removal of enucleated tissue in local anesthesia	0 (0)	1 (2.2)	1 (1.1)	0.267
Hydronephrosis due to ureteric orifice injury	Ureteral stent (double J stent)	0 (0)	1 (2.2)	1 (1.1)	0.267
Clavien grade 3b complications ( <i>n</i> = 4 of 94; 4.3%)					
Incomplete morcellation (blade malfunction)	Secondary morcellation	0 (0)	1 (2.2)	1 (1.1)	0.267
Hemorrhage/clot retention	Cystoscopy with clot evacuation, coagulation of prostate fossa	1 (2.1)	2 (4.3)	3 (3.2)	0.397

ThuVEP thulium laser enucleation of the prostate, HoLEP holmium laser enucleation of the prostate

<sup>a</sup> During hospital stay

<sup>b</sup> During 4-week follow-up

An immediate and significant improvement of voiding parameters ( $Q_{max}$ , PVR) and symptom scores (IPSS, QoL) after ThuVEP and HoLEP was shown at discharge and continued to do so during 4-week follow-up in our series, comparable to TURP [4, 5], OP [4, 5], HoLEP [4, 5, 15, 23, 24], BipoleP [15–21], GreenLEP [23], ThuLEP [24, 25], and ELEP [26]. We could confirm that both, ThuVEP and HoLEP, are size-independent procedures, since the median prostate volume was 80 ml with fifty (53.2%) patients having been treated with prostate volumes  $\geq 80$  ml. This size-independence of EEP could be already demonstrated in RCTs for HoLEP [4, 5, 23], BipoleP [16–21], GreenLEP [23], and DiLEP [22].

Median postoperative stay and catheterization times were 2 days in our series without differences between ThuVEP and HoLEP, which is shorter than in TURP [1, 4, 5, 16] and OP [2, 4, 5, 17–21]. Regarding postoperative stay and catheterization times after transurethral EEP procedures, shorter catheterization times and postoperative stay have been reported in enlarged prostates ( $\geq 80$  ml) for HoLEP [4, 5, 23], BipoleP [19, 21, 22], and GreenLEP [23], but also longer catheterization times and postoperative stay for BipoleP [17, 19, 20, 22] and DiLEP [22] was shown. In this series, the foley catheter was removed routinely 48 h after surgery and the strategy of keeping the

patient in the hospital until able to void adequately was followed. However, catheterization times and hospital stay are most likely triggered by differences in reimbursement in the different national health systems and should be taken into account when comparing these parameters from different series [10].

Interestingly, the enucleation time was significantly shorter in ThuVEP compared to HoLEP. The continuous wave mode of the Thulium:YAG laser might allow a faster enucleation compared to the pulsed mode of the Holmium:YAG laser. On the other hand, the coagulation depth of the Thulium:YAG laser (2 mm) is more shallow compared to the Holmium:YAG laser (4 mm). Therefore, more time might be required for the final coagulation after ThuVEP compared to HoLEP, which might explain why there were no differences between the total operative times of the procedures.

Clavien 1 (13.8%), 2 (3.2%), 3a (2.1%), and 3b (4.3%) complications occurred without differences between the groups. The overall CR was 23.4% and was significantly higher after HoLEP compared to ThuVEP (12.5 vs. 33.3%). This was mainly due to the higher recatheterization rate after HoLEP compared to ThuVEP (15.2 vs. 2.1%), which was a surprising result of our study. One possible explanation would be that the apical detachment of the lateral lobes

**Table 5** Baseline and follow-up data

	Median (IQR) Preop	Median (IQR) Discharge	Median (IQR) 1-mo follow-up	Baseline vs. 1-mo Follow-up <i>p</i> value
<b>IPSS</b>				
Total	20 (16–25)	n.a.	10 (6–14.5)	<0.001
ThuVEP	20 (16–25)	n.a.	9 (6–14)	<0.001
HoLEP	22 (15–26)	n.a.	11 (7–16)	<0.001
<i>p</i> value	0.809	–	0.429	
<b>QoL</b>				
Total	4 (4–5)	n.a.	3 (1–4)	<0.001
ThuVEP	4 (4–5)	n.a.	2 (1–3)	<0.001
HoLEP	4 (4–5)	n.a.	3 (2–5)	≤0.005
<i>p</i> value	0.889	–	≤0.040	
<b><math>Q_{max}</math> (ml/s)</b>				
Total	10.7 (6.43–14.85)	16 (10.6–19) <sup>a</sup>	22 (16.8–27)	<0.001
ThuVEP	9.6 (6.2–12.4)	16 (11.7–19.4) <sup>a</sup>	22 (15–27.5)	<0.001
HoLEP	12.1 (7.2–15)	13 (8.4–18) <sup>a</sup>	21.3 (17.7–27.5)	<0.001
<i>p</i> value	0.181	0.162	0.800	
<b>PVR<sup>b</sup> (ml)</b>				
Total	100 (41.75–200)	30 (0–82.5) <sup>a</sup>	20 (0–60)	<0.001
ThuVEP	100 (26.75–237.5)	38.5 (0–90) <sup>a</sup>	14 (0–60)	<0.001
HoLEP	105 (48.25–200)	20 (0–80) <sup>a</sup>	30 (0–67.5)	<0.001
<i>p</i> value	0.962	0.674	0.351	

Data indicated as median (interquartile range)

*ThuVEP* thulium laser enucleation of the prostate, *HoLEP* Holmium Laser Enucleation of the Prostate, *IPSS* International Prostate Symptom Score, *QoL* quality of life,  $Q_{max}$  maximum urinary flow rate, *PVR* post-voiding residual urine, *n.a.* not analyzed

<sup>a</sup> Compared with baseline

<sup>b</sup> Except those in urinary retention

from the apico-mucosal strip might be different between the thulium laser and the holmium laser. The energy of the Thulium:YAG laser is delivered in a continuous wave mode, which allows clear and smooth incisions, contrary to the pulsed Ho:YAG laser. Therefore, remnants of the apico-mucosal strip might be responsible for the differences in the recatheterization rates. However, the total CR as well as the HoLEP recatheterization rate in our study is well comparable with the literature [4, 5, 15]. Other non-interventional perioperative complications in this PRT were clot retention without surgical revision (4.3%) and UTI (2.1%). These CRs were comparable with current TURP [4, 5] or OP series [4, 5, 18–20] and comparable with HoLEP [4, 5], BipoleP [15–23], GreenLEP [23], ThuLEP [24, 25], ELEP [26], and DiLEP [27]. To note, the transfusion rate was very low (1.1%), although 18 patients were treated on ongoing anticoagulant therapy in the ThuVEP ( $n = 9$ ) and HoLEP ( $n = 9$ ) group. This supports the excellent haemostatic properties of both lasers and ensures the safety of ThuVEP and HoLEP in anticoagulant patients [28, 29]. The overall immediate perioperative reoperation (Clavien 3a/b) rate was 4.3% and mainly consisted of three patients (3.2%) treated with ongoing anticoagulant therapy who

required coagulation of the prostate fossa due to postoperative bleeding. Therefore, the reintervention rates were well comparable with HoLEP and ThuVEP series [4, 5, 7–10, 15, 23] and other EEP procedures such as BipoleP [15–23], GreenLEP [23], and ThuLEP [24, 25].

With this study we present the first PRT comparing the ThuVEP procedure with the well established EEP procedure, the HoLEP technique. However, our study has several limitations: The current unicentric PRT was not powered to detect non-inferiority of ThuVEP over HoLEP, which seems to be the main limitation. All procedures were performed by two experienced surgeons (AJG, CN), who had done more than 500 ThuVEP and HoLEP procedures each. This might be a reason for the low Clavien 3a/b (4.3%) CR in this PRT and the low transfusion rate (1.1%), despite of the facts that median prostate size was 80 ml and 19.1% of the patients were treated under ongoing anticoagulant treatment. Finally, all HoLEP procedures were carried out as low powered (39.6 W) HoLEP and compared to 90 W ThuVEP. A RCT comparing low powered with high powered HoLEP has not been published so far. The only difference in clinical parameters found between 90 W ThuVEP and 39.6 W HoLEP was the recatheterization rate and QoL at



4-week follow-up, which were, however, within the range given in the literature [4, 5]. As a last limitation, a clear differentiation of the ThuVEP technique from the ThuLEP technique is difficult to define, since there are smooth transitions from each technique: ThuLEP is a blunt enucleation technique with Tm:YAG laser support using the beak of the resectoscope for dissecting off the adenoma from the pseudocapsule of the prostate, while the Tm:YAG laser is continuously applied to the layer of enucleation for dissecting off the prostate from the surgical pseudocapsule in ThuVEP [30].

## Conclusions

ThuVEP and HoLEP are both safe and effective procedures for the treatment of symptomatic BPO in enlarged prostates. Both procedures give equivalent and satisfactory micturition improvement with low morbidity at 1-month follow-up.

**Author contributions** CN: Project development, data collection, manuscript writing, data analysis and interpretation. BB: Data collection and manuscript writing. CT: Data collection. CM: Data collection. AVB: Data collection. TRWH: Manuscript writing, data analysis and interpretation. AJG: Project development, manuscript writing, data analysis and interpretation.

## Compliance with ethical standards

**Ethical standards** All patients were treated after obtaining informed consent, following institutional review board approval.

**Conflict of interest** The authors have nothing to disclose.

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